A STUDY ON THE SUPERCONDUCTING PROPERTIES OF $YBa_2Cu_{3-X}Nb_XO_Y$ THIN FILMS

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ABSTRACT

Effect of Niobium substitution at the copper site in $YBa_2Cu_3O_{7-x}$ was studied in thin film form. The films were deposited by laser ablation technique using the targets of the $YBa_2Cu_{3-x}Nb_xO_y$ where x = 0.0, 0.025, 0.05, 0.1, 0.2, 0.4, 0.8 and 1.0 under identical deposition conditions on $SrTiO_3$ <100> substrates. Films were characterized by XRD, resistivity, I-V and J_C measurements. Films made from x = 0.025 and 0.05 concentrations of Nb substituted targets showed relatively improved superconducting properties compared to that of undoped films. The best J_C realized for x = 0.025 Nb concentration was 1.8×10^6 A/cm^2 and for 0.05 Nb concentration it was 3.2×10^6 A/cm^2 at 77K. However, degradation of the superconducting properties, with the increase of $x \geq 0.1$ Nb concentration and drastic suppression and complete loss of superconductivity was noticed for $x \geq 0.4$. The growth of impurity phase YBa_2NbO_6 for x = 0.1 and above of Nb concentration was noticed from XRD patterns. However, the site occupancy of Nb could not be confirmed from these studies.

INTRODUCTION

Recent research trends in high temperature superconductivity(HTSC) have aimed at the improvement of superconducting properties by substitution or addition of other elements. However, substitution at Cu sites of HTSC compound has resulted in drastic degradation of superconducting properties [1-3]. The superconducting properties of $YBa_2Cu_3O_{7-x}$(YBCO) have revealed that the Cu-O plane and chain assembly is primarily responsible for the superconductivity and the main contribution to the density of states at the fermi level comes from the copper 3d and the oxygen 2p hybridization states. Hence, many researchers thought that the substitution for Cu by transition metals should produce substantial changes in the superconducting properties. The substitution of Nb in bulk has shown [4,5] that Nb substitution has not made any substantial improvement in the superconducting properties of YBCO, however it has shown improvement in mechanical properties. Moreover, substitution of Nb and Ta at Cu1 site in YBCO system has been confirmed by neutron diffraction analysis [10]. In the present study we report the superconducting properties of Nb substituted ($YBa_2Cu_{3-x}Nb_xO_y$) thin films.

EXPERIMENTAL

The targets for pulsed laser deposition (PLD) were prepared in the nominal stoichiometric compositions $YBa_2Cu_{3-x}Nb_xO_y$ where x = 0.0, 0.025, 0.05, 0.10, 0.2, 0.4, 0.8 and 1 using high pure chemicals. Thin films were made from the above targets using a Lambda Physik 301:KrF 248 nm excimer laser and a 300nm focal length quartz lens for beam focusing with a pulse width of 25 ns and a 1-10 Hz variable frequency. The target to substrate distance was maintained constant at 4.5cm, at a substrate temperature of 700°C and in an oxygen partial pressure of 200 mTorr. Thin films of 2000 A thickness of the above mentioned targets were deposited on $SrTiO_3$ <100> substrate under identical deposition conditions for comparison. Films were characterized by

XRD, SEM, four probe electrical resistivity and I-V characteristics and critical current density J_c measurements were done on 20μm and 1mm long microbridges.

RESULTS AND DISCUSSIONS

The XRD patterns have shown c-axis oriented films (fig.1) and with the increase of Nb concentration growth of a secondary phase YBa_2NbO_6 [6]has been identified. The transition temperatures for x = 0.0, 0.025, 0.05 are around 89K, 89.2K and 89.6K respectively. The critical current densities are 1.2 x 10^6 A/cm^2 1.8x 10^6 A/cm^2 and 3.2x 10^6 A/cm^2 respectively. D.Kumar et al [7] have reported that the nature of grain boundaries in undoped and doped films can be studied using a model proposed by De. Gennes[8] and Clarke[9]. As per this model, the slope of the $\sqrt{J_c}$ vs T_c -T will give a measure of the grain boundary domain thickness. When the slope is large, it indicates perfect alignment of grains and hence reduction of weak links which results in good quality film. From fig.2b, it is evident that the slope of Nb substituted films for the concentrations 0.025 and 0.05 is larger compared with undoped YBCO film. Our scanning electron micrographs have also resulted in featureless grain structure which may be due to the perfect alignment of grains during the growth process, however, particulates still exist (fig.4). The possible explanation for the improvement of critical current densities may be due to the fact that substitution of Nb (for lower concentrations only) at Cu1 sites in the basal plane, introduces extra oxygen at the vacant O5 which results in the change of oxygen coordination of the Cu1 cation from planar to octahedral coordination [11].

With the increase in Nb concentration for x ≥ 0.1 degradation and complete loss of superconductivity has been observed (fig 2a). It is due to the stabilization of YBa_2NbO_6 phase at higher concentrations. However, it has been realized that substitution of Nb up to x = 0.05 for Cu will improve the microstructural and superconducting properties of YBCO thin films compared to undoped YBCO films deposited under identical conditions.

CONCLUSIONS

The effect of Nb substitution for Cu on the superconducting properties of YBCO thin films has been investigated. It is noticed that no significant change in the orthorhombcity of the crystal structure or in T_c has been observed in YBCO thin films for Nb substitution up to x = 0.05 concentration, however, increase in J_c up to x = 0.05 of Nb concentration compared to that of undoped YBCO thin films has been realized. Degradation of superconducting properties and complete loss of superconductivity with the increase of Nb concentration confirm that Nb substitution has not made any substantial improvement on the superconducting properties even though it exists in +5 valance state. It can not be concluded from this study that whether Nb has substituted for Cu in YBCO lattice. A more detailed study is needed.

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REFERENCES :

1. Gang Xiao, F.H. Strelty, A.Gavain, Y.W.Du and C.L. Chien : Phys. Rev. B 35(1987) 8782.
2. M.S.Islam. and Baetzold : Phys. Rev. B. 40(1989) 10926.
3. S.B.Ogale, M.Vedavyas, G.S.T.Bendre and S.M. Kanetkar : Appl. Phys . Lett. 61(1992) 2105.
4. M.Kuwabara and N.Kusaka : Jpn. J. Appl. Phys 27(1988) L1504.
5. Suresha N.G., Higo.S, Hakuraku.Y, Otawa.T, Honjo.Y and Ogushi.T : Int. J. Mod. Phys. B2(1988) 435.
6. Paulouse K.V., Koshy. J and Damodaran A.D.: Jpn. J. Appl

Phys.30(1991) L458.
7. D.Kumar et al : Appl. Phys. Lett. 62(1993) 3522.
8. P.G.DeGennes : Rev. Mod. Phys. 36(1964) 225.
9. J. Clarke : Proc. R. S. London A 308(1969) 447.
10. C.Greaves and P.R.Slater : Physica C161 (1989) 245.
11. Rey M.J., Dehaudt P.H., and Joubert J. : Physica C 167(1990) 162.

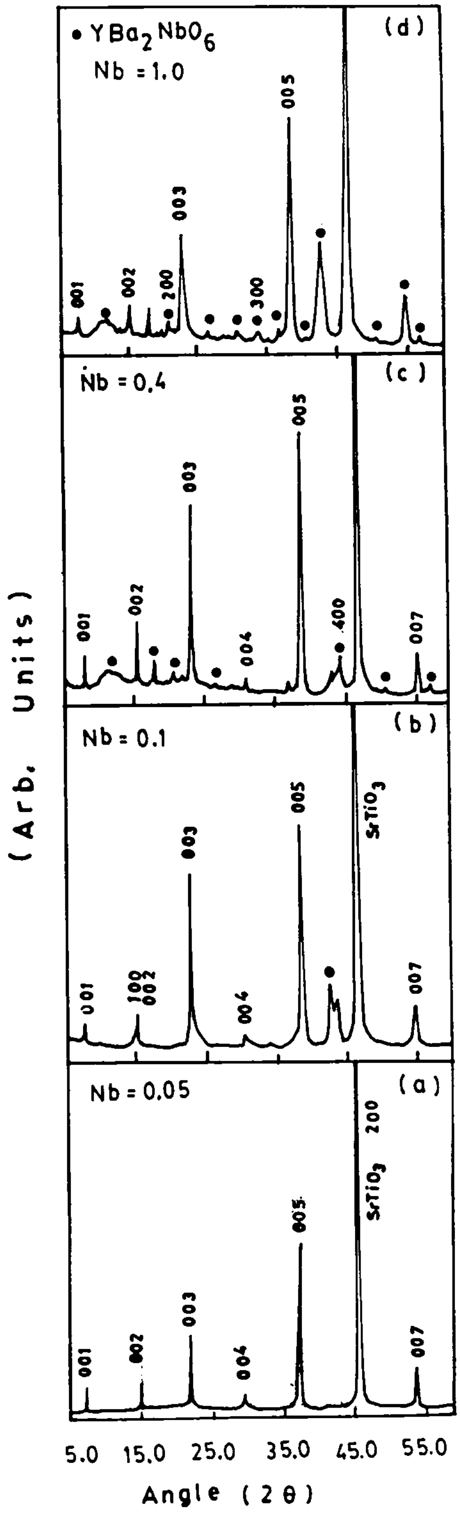

Figure 1.- X-Ray diffraction pattern of Nb substituted films.

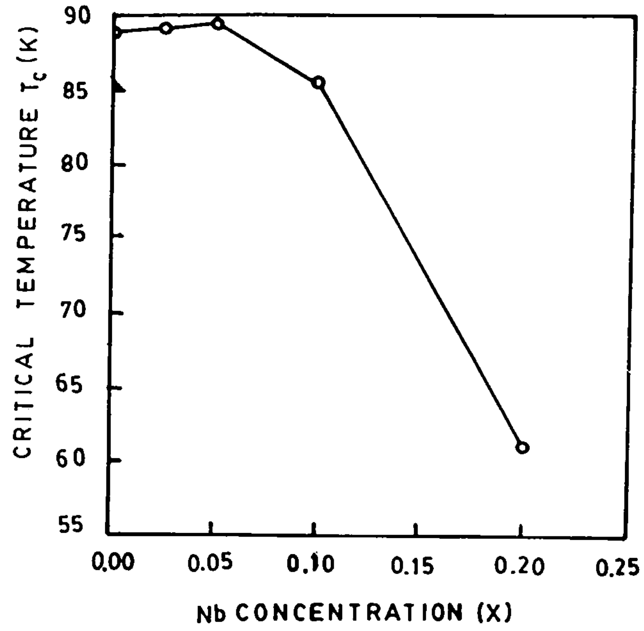

Figure 2.-Nb concentration (x) vs critical temperature (T_c) of the Nb substituted thin films.

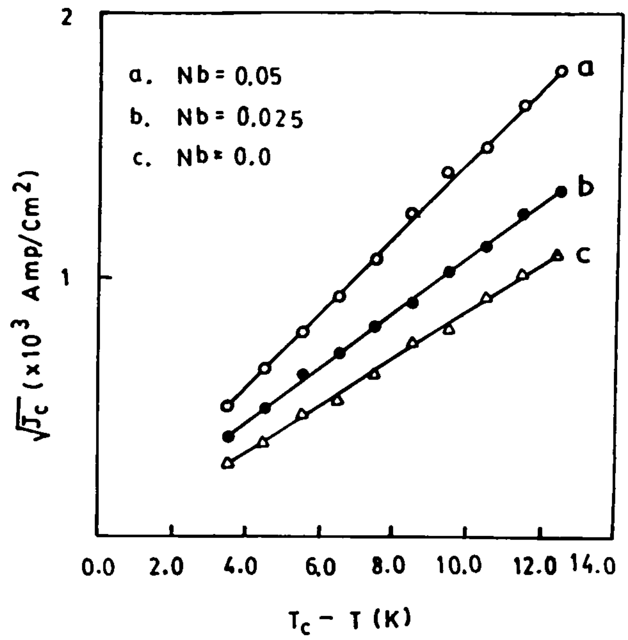

Figure 3.- T_c-T vs $\sqrt{Jc}$ of Nb substituted and undoped YBCO thin films.

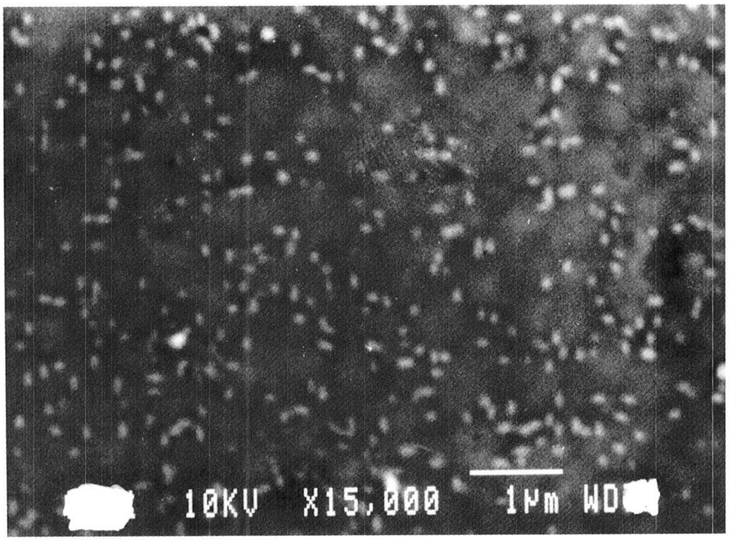

Figure 4.- Scanning electron micrograph of 0.05 concentration of Nb substituted film.